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A control and telemetering system, using light beams, for a van de Graaff generator

By Eskil Möller

With 9 figures in the text

SUMMARY

A system, using light beams, for remote control and telemetering, has been designed for the control of the equipment in the terminal of an electrostatic generator. Ten variables can be changed, one at a time. The desired function is chosen by a dial, and the position of the function (i.e. a voltage) is read on an instrument on the control panel at the same time. The system is used with dual control. The telemetering system can be used for measurements of currents also in the microampere range.

1. Introduction

A common method to achieve control possibilities of the ion source in a van de Graaf accelerator is having a mechanical link (wires of nylon, rods of lucite) between the earth potential side of the machine and the high voltage electrode. The measurement of electrical quantities is in many machines made by reading instruments in the terminal by a telescope and mirrors in suitable positions.

In accelerators for voltages above 2 Mev there is a certain danger associated with rods and wires as electrical breakdown may occur along them and disturb the function of the accelerator. Reading of instruments by optical means may be difficult if the machine must be remotely operated in case of dangerous radiations. A wireless system eliminates these difficulties.

A system for control by light signals has been designed for the van de Graaff generator at the Department of Physics, University of Lund. This generator is built for 4 MV and is mounted horizontally in a pressure vessel at a pressure of 10 atmospheres. The mechanical frame consists of three textolite tubes with a smallest inner diameter of 8 cm. These are used as light paths. The system is used with dual control, having one control panel in the accelerator hall and one in a room, protected from radiation.

It is necessary to aim at a high degree of reliability of the control system because of its inaccessibility in the tank. Simple principles and a small number of electron tubes and other sensitive components should aid to this. The electron tubes used have been tested to withstand the high pressure. Because of the vibrations from the pulley in the high voltage electrode, pentodes are avoided in favour of triodes.

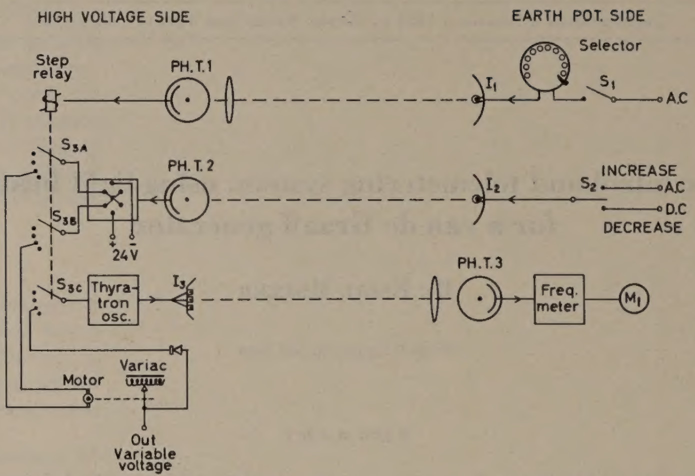

Fig. 1. Principles of the control and telemetering system.

2. Principles

Fig. 1 shows the principles of the control system. When the switch S_1 is closed, A.C. passes through the dial to the lamp I_1. If a number is dialled, the current to the lamp is interrupted and it flashes a number of times. In the high voltage electrode the light is received by a phototube PH.T.1, and when the lamp flashes, a step relay receives the same number of impulses. The step relay works like a 5-pole 12-position switch. Two of the poles, $S_{3\text{A}}$ and $S_{3\text{B}}$, close the circuit to a D.C. permanent magnet motor, being able to turn a variac or potentiometer. This motor can now be turned in either direction by the switch S_2. If S_2 is connected to D.C., the lamp I_2 lights up. The light is received by PH.T.2, which by a relay connects 24 V D.C. to the motor which runs as long as the light is on. If S_2 is turned to A.C. instead, the lamp lights up, but with an alternating component of 100 c/s. When the voltage from PH.T.2 has this component, the polarity of the D.C. voltage to the motor is reversed and the motor rotates in the opposite direction. In this way voltages can be decreased or increased.

At the same time as the contacts $S_{3\text{A}}$ and $S_{3\text{B}}$ of the step relay connect the selected motor, the contact $S_{3\text{C}}$ is connected to the associated point for measurement of voltage. This voltage is fed to a self-running thyratron oscillator, the frequency of which is proportional to the D.C. input voltage. Pulses from the oscillator modulate a number of neon bulbs. The light from these is received by the phototube PH.T.3 and the frequency is read on the instrument M_1.

The selected voltage being adjusted to the desired value, the switch S_1 is opened, and the lamp I_1 goes out. The step relay returns to its starting position. In Fig. 1 only one of the ten channels are shown for the sake of plainness. The step relay has two poles more, which are used for a special purpose.

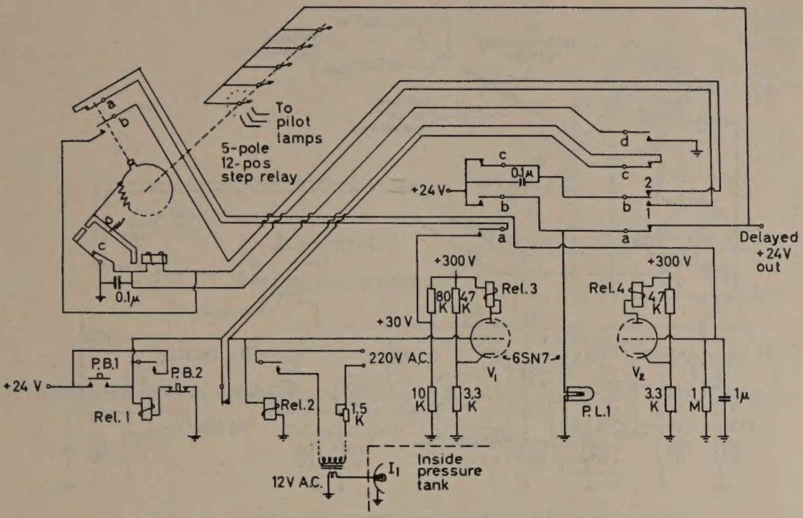

Fig. 2. Selecting system: Transmitter.

3. Detailed description

(a) Transmitter (selecting system)

The control system can be operated from two separate places. Therefore push-buttons and a 24 Volts D.C. relay system is used, instead of the switches in Fig. 1. Besides giving impulses to the lamp I_1, the dial operates a step relay with indicator lamps, showing the selected number. Fig. 2 shows the transmitter of the selecting system. (In the schemes circuits for dual control are not shown as they are simple in principle.) The lower left part corresponds to the transmitter in Fig. 1. The purpose of the other components is (1) to indicate the selected number, (2) to prevent the use of the increase-decrease system while the step relay is in action, (3) to bring about the return of the step relay when the transmitter lamp is put out, and (4) to prevent a new number from being dialled when the step relay is not in its starting position.

The step relay is of a type being used in small telephone exchanges. It has three auxiliary contacts. The first of these, *a*, is closed and the second, *b*, open when, and only when, the relay is in its starting position. The contact *a* is used for purpose (2) above, and the contact *b* combined with the third contact, *c*, the function of which is understood from Fig. 2, is used to achieve the return of the relay to the starting position.

When the button P.B.1 is pressed, REL. 1, 2, 3, and 4 are energized, and the lamp I_1 is lit. This lamp is an autocar lamp, Philips 12 V, 15 W. When the dial rotates, the voltage to REL. 2 is interrupted a number of times and the lamp I_1 flashes. The step relay in Fig. 2 runs at the same time because of current impulses through contact *c* of REL. 3. The relay having left its starting position, the RC circuit in the grid of V_2 starts discharging, and after 2 seconds V_2 becomes non-conducting. Then 24 V

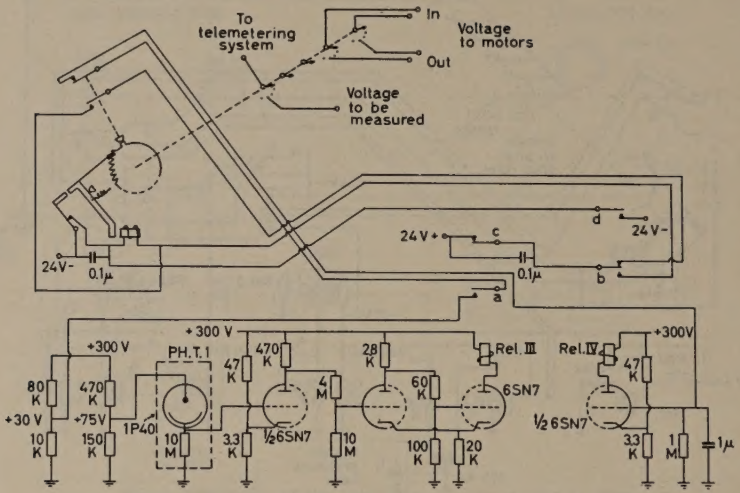

Fig. 3. Selecting system: Receiver.

D.C. passes through contact *a* of REL. 4, to the step relay switch, which distributes voltage to the pilot lamps, showing the number chosen, and to the increase-decrease system, which can be used from now on. If the push-button P.B.2 is pressed, the lamps go out, and the step relay returns automatically to its starting position.

(*b*) *Receiver* (*selecting system*)

The receiver in the terminal is shown in Fig. 3. The phototubes used are of type 1P40. PH.T.1 is followed by a D.C. amplifier and a Schmitt trigger. The relays III and IV correspond to relays 3 and 4 in the transmitter. The operation of the receiver is analogous to the operation of the corresponding circuits of the transmitter. The changes which may occur in the D.C. amplifier from tube aging are compensated by adjusting the current to the lamp I_1 in the transmitter by the resistor in the primary of its transformer (Fig. 2).

(*c*) *Increase–decrease system*

Fig. 4 shows the transmitter, which can be used when the delayed 24 V comes from the selector transmitter. The data of the lamp I_2 is 12 V, 35 W. In the receiver, Fig. 5, REL. I is energized, when the lamp I_2 is fed by D.C. If there is an alternating component in the light, it is identified by the tuned amplifier and REL. II is energized too. In the first case the voltage to the motor is of one polarity, in the second case REL. II reverses the polarity.

(*d*) *Telemetering system*

All voltages and currents, which are to be measured, are converted to give voltages in the range 0 to 13 V. The point to be measured is selected by the step relay and is

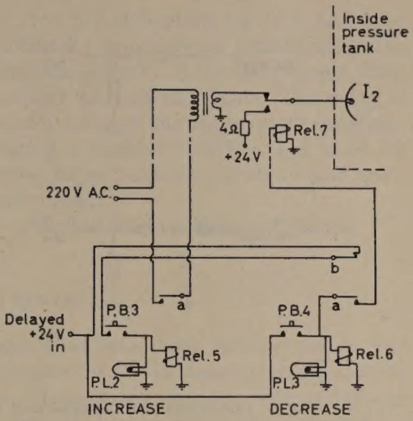

Fig. 4. Increase–decrease system: Transmitter.

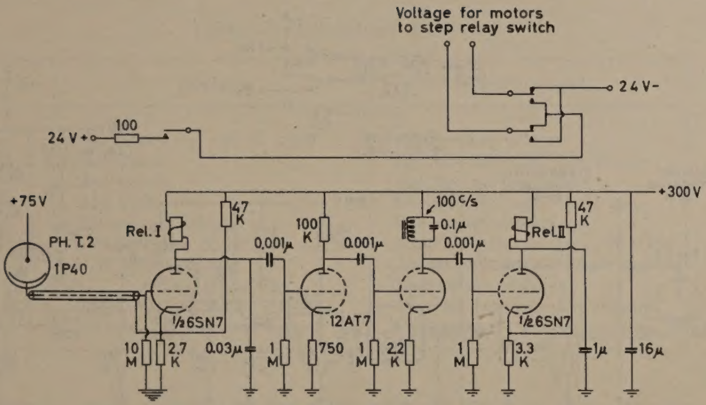

Fig. 5. Increase–decrease system: Receiver.

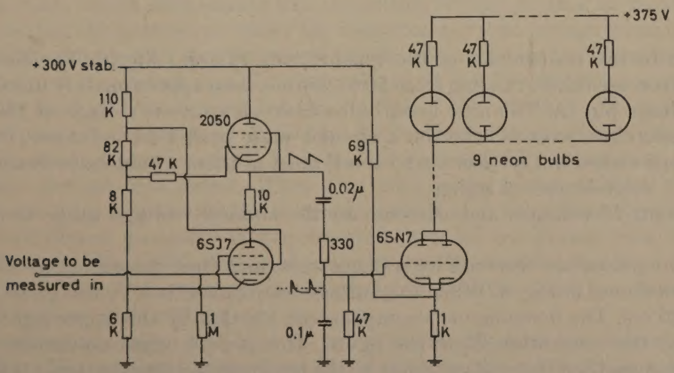

Fig. 6. Telemetering transmitter.

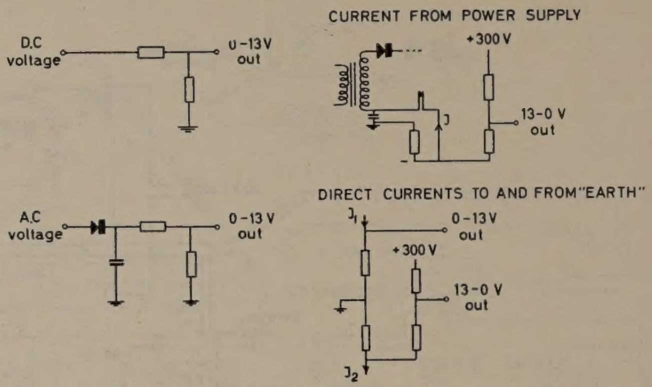

Fig. 7. Conversion of voltages and currents for the telemetering transmitter.

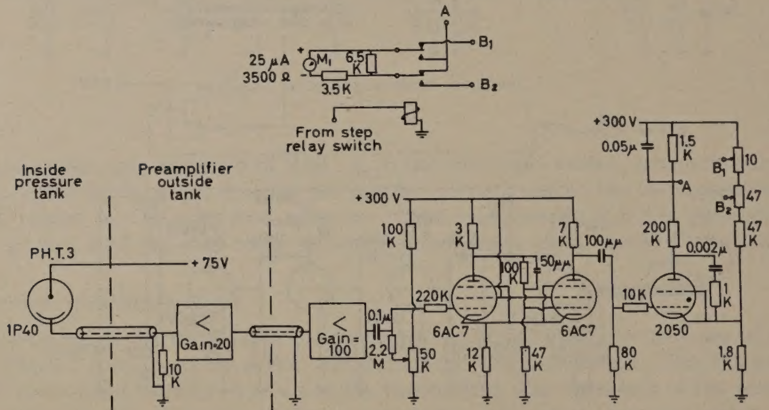

Fig. 8. Telemetering receiver.

connected to the transmitter of the telemetering system, Fig. 6. The frequency of the thyratron oscillator, ranging from 20 to 250 c/s, is an approximately linear function of the voltage put in. The nine neon bulbs have an ignition voltage of 150 V. They are mounted close to each other on a circular plate with a 45° reflector. Parallelling many lamps makes the system work even if most of them would be useless because of implosion, short-circuit or aging.

Conversion of voltages and currents to the suitable voltage range is illustrated in Fig. 7.

The light pulses are received by a photo tube and their frequency measured. The circuits are shown in Fig. 8. When the voltage telemetered is 0 V, the pulse frequency is about 20 c/s. The instrument is compensated for this by the upper right potentiometer with the connection B_1 in the figure. This is done when no number has been dialled, because then the voltage input to the telemetering transmitter is 0 V. Measuring negative voltages, the instrument would give full deflection for 0 V and zero deflection for a high negative voltage. This difficulty is overcome by changing the connection for compensation to B_2 and reversing the polarity of the instrument. This switching is made by a relay, shown in the upper part of the figure. The relay is operated by the delayed 24 V, connected by the step relay on the appropriate numbers. The compensation in this case is done by taking a number which is not used for measurement in the terminal. Then the incoming pulse frequency is 20 c/s and compensation is done to full deflection of the instrument.

The meaning of the instrument readings is obtained from calibration curves.

4. Use of the system

From what has been said above, it appears that two push-buttons and a dial are used for the selecting system, two push-buttons for the increase-decrease system and a 25 microamperes instrument for the telemetering system. The telephone directory is shown in Table 1. Some operations tabulated there are achieved by special circuits, made possible by the many poles of the step relay. No. 0 is used to turn off the ion beam quickly. By that the delayed 24 V in the high voltage electrode operates a relay, which disconnects the extraction voltage as long as No. 0 stands. At the same time the instrument shows the magnitude of that voltage when connected again, and the voltage may be changed to the desired value by the increase–decrease system. If No. 9 is selected, a calibration voltage of +9 V will be connected to the telemetering system. This is used for the control of the stability. No. 9 is used for another purpose too. By pressing the button for decrease, the whole equipment in the high voltage electrode is turned off. This has been arranged by connecting a relay in this position instead of a motor. When this relay is energized, another relay gets 24 V, and one of its contacts makes it remain energized. At the same time the power from the belt-driven generator is disconnected from all equipment except the last mentioned relay. This possibility is of value when the machine has been open and must be run for some days to get rid of absorbed moisture and to collect dust on on suitable places with voltage on.

Table. 1. Telephone directory.

No.	Control	Measurement
0	Ion beam cut off at once	Extraction voltage
1	Gas valve	Current through ion source
2	Gas valve	Voltage to gas valve
3	Gas valve	Current through H.F. osc.
4	Focussing voltage	Focussing voltage
5	Switch from H_2 to He	Kind of gas: $25 = H_2$, $20 = He$
6	H.F. power	Anode voltage of H.F. osc.
7	—	Extraction voltage
8	Extraction voltage	Current through ion source
9	Terminal equipment turned off	Calibration voltage

The telemetering system has been of value in investigating the current losses in the machine. The accelerator has been tested without the acceleration tube. Some-

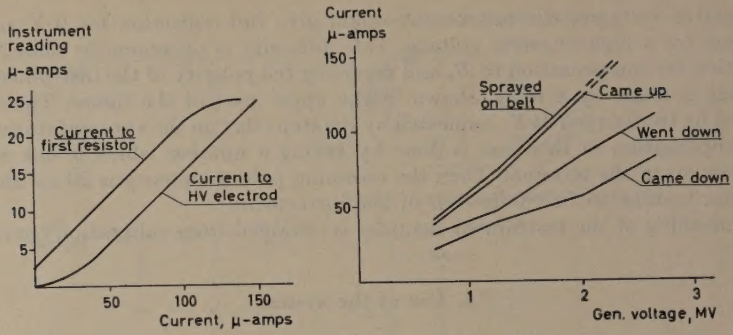

Fig. 9. Search for current losses.

times only a fraction of the current, having been charged to the belt, has come down through the resistance chain from the terminal to earth potential. To localize the losses, the currents reaching and leaving the terminal were telemetered. Fig. 9 shows calibration curves for these measurements and an example of the results. In this example it was concluded that there was no loss of the charge from the belt, but that corona or leakage currents from the high voltage electrode must be supposed.

ACKNOWLEDGEMENTS

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Department of Physics, University of Lund, Lund, Sweden.

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